The Advanced Technology Microwave Sounder (ATMS): New Capabilities for Atmospheric Sensing

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Advanced Technology Microwave Sounder (ATMS)

ATMS is a 22 channel MW sounder
Frequencies range from 23-183 GHz
Total-power, two-point external calibration
Continuous cross-track scanning, with torque & momentum compensation
Orbits: 833 km (JPSS); 824 km (NPP); sun-synchronous
Thermal control by spacecraft cold plate
Contractor: Northrop Grumman Electronics Systems (NGES)
ATMS Development

- ATMS NPP unit ("F1") developed by NASA/Goddard
  - ATMS NPP unit delivered in 2005
  - ATMS JPSS-1 unit ("F2") currently in development
    (antenna and TVAC testing in 2011/12, delivery in 2012)

- Principal challenges/advantages:
  - Reduced size/power relative to AMSU
    Scan drive mechanism
    MMIC technology
  - Improved spatial coverage (no gaps between swaths)
  - Nyquist spatial sampling of temperature bands (improved information content relative to AMSU-A)
Atmospheric Transmission at Microwave Wavelengths

ATMS channels

The frequency dependence of atmospheric absorption allows different altitudes to be sensed by spacing channels along absorption lines.
# Spectral Differences: ATMS vs. AMSU/MHS

ATMS has 22 channels and AMSU/MHS have 20, with polarization differences between some channels:

- **QV** = Quasi-vertical; polarization vector is parallel to the scan plane at nadir
- **QH** = Quasi-horizontal; polarization vector is perpendicular to the scan plane at nadir

<table>
<thead>
<tr>
<th>AMSU/MHS</th>
<th>ATMS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ch</strong></td>
<td><strong>GHz</strong></td>
</tr>
<tr>
<td>1</td>
<td>23.8</td>
</tr>
<tr>
<td>2</td>
<td>31.399</td>
</tr>
<tr>
<td>3</td>
<td>50.299</td>
</tr>
<tr>
<td>4</td>
<td>52.8</td>
</tr>
<tr>
<td>5</td>
<td>53.595 ± 0.115</td>
</tr>
<tr>
<td>6</td>
<td>54.4</td>
</tr>
<tr>
<td>7</td>
<td>54.94</td>
</tr>
<tr>
<td>8</td>
<td>55.5</td>
</tr>
<tr>
<td>9</td>
<td>fo = 57.29</td>
</tr>
<tr>
<td>10</td>
<td>fo ± 0.217</td>
</tr>
<tr>
<td>11</td>
<td>fo±0.3222±0.048</td>
</tr>
<tr>
<td>12</td>
<td>fo±0.3222±0.022</td>
</tr>
<tr>
<td>13</td>
<td>fo±0.3222±0.010</td>
</tr>
<tr>
<td>14</td>
<td>fo±0.3222±0.0045</td>
</tr>
<tr>
<td>15</td>
<td>89.0</td>
</tr>
<tr>
<td>16</td>
<td>88.2</td>
</tr>
<tr>
<td>17</td>
<td>157.0</td>
</tr>
<tr>
<td>18</td>
<td>183.31 ± 1</td>
</tr>
<tr>
<td>19</td>
<td>183.31 ± 3</td>
</tr>
<tr>
<td>20</td>
<td>191.31</td>
</tr>
<tr>
<td>21</td>
<td>183.31 ± 1.8</td>
</tr>
<tr>
<td>22</td>
<td>183.31 ± 1</td>
</tr>
</tbody>
</table>

- **Exact match to AMSU/MHS**
- **Only Polarization different**
- **Unique Passband**
- **Unique Passband, and Pol. different from closest AMSU/MHS channels**
Spatial Differences: ATMS vs. AMSU/MHS

<table>
<thead>
<tr>
<th>Beamwidth (degrees)</th>
<th>ATMS</th>
<th>AMSU/MHS</th>
</tr>
</thead>
<tbody>
<tr>
<td>23/31 GHz</td>
<td>5.2</td>
<td>3.3</td>
</tr>
<tr>
<td>50-60 GHz</td>
<td>2.2</td>
<td>3.3</td>
</tr>
<tr>
<td>89-GHz</td>
<td>2.2</td>
<td>1.1</td>
</tr>
<tr>
<td>160-183 GHz</td>
<td>1.1</td>
<td>1.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Spatial sampling</th>
<th>ATMS</th>
<th>AMSU/MHS</th>
</tr>
</thead>
<tbody>
<tr>
<td>23/31 GHz</td>
<td>1.11</td>
<td>3.33</td>
</tr>
<tr>
<td>50-60 GHz</td>
<td>1.11</td>
<td>3.33</td>
</tr>
<tr>
<td>89-GHz</td>
<td>1.11</td>
<td>1.11</td>
</tr>
<tr>
<td>160-183 GHz</td>
<td>1.11</td>
<td>1.11</td>
</tr>
<tr>
<td>Swath (km)</td>
<td>~2600</td>
<td>~2200</td>
</tr>
</tbody>
</table>

ATMS scan period: 8/3 sec; AMSU-A scan period: 8 sec
ATMS measures 96 footprints per scan (30/90 for AMSU-A/B)
## Summary of Key Sensor Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>PFM Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Envelope dimensions</td>
<td>70x60x40 cm</td>
</tr>
<tr>
<td>Mass</td>
<td>75 kg</td>
</tr>
<tr>
<td>Operational average power</td>
<td>100 W</td>
</tr>
<tr>
<td>Operational peak power</td>
<td>200 W</td>
</tr>
<tr>
<td>Data rate</td>
<td>30 kbps</td>
</tr>
<tr>
<td>Absolute calibration accuracy</td>
<td>0.6 K</td>
</tr>
<tr>
<td>Maximum nonlinearity</td>
<td>0.35 K</td>
</tr>
<tr>
<td>Frequency stability</td>
<td>0.5 MHz</td>
</tr>
<tr>
<td>Pointing knowledge</td>
<td>0.03 degrees</td>
</tr>
<tr>
<td>NEΔT</td>
<td>0.3/0.5/1.0/2.0 K</td>
</tr>
</tbody>
</table>
ATMS Post-Launch Calibration/Validation in a Nutshell

- Post-launch is Cal/Val has four phases: Activation, Checkout, Intensive Cal/Val, and Long-term Trending

- Tasks within the phases can be categorized:
  - Sensor Evaluation: interference, performance evaluation, etc.
  - TDR/SDR Verification: geolocation, accuracy, etc.
  - SDR Algorithm Tunable Parameters: bias correction, space view sector, etc.

- Activation Phase: Sensor is turned on and a sensor functional evaluation is performed; ATMS is collecting science data

- Checkout Phase: Performance evaluation and RFI evaluations

- Intensive Cal/Val: Verification of SDR attributes such as geolocation, resampling, brightness temperature accuracy (Simultaneous Nadir Overpass, Double Difference, radiosondes/NWP simulations, aircraft verification campaigns), and satellite maneuvers
ATMS 90-GHz Channel
Passive Infrared Measurements Provide High Spatial Resolution

The NPP CrIS sensor provides 15km horizontal and 1km vertical resolution.
Passive Microwave Measurements Provide Low Spatial Resolution, but Penetrate Clouds

The NPP ATMS sensor provides 35km horizontal and 3km vertical resolution
AMSU-A: Large, Positive Forecast Impact

Observation impact: 3dVar DAS & Forecasts
Accumulated forecast error reduction due to various observing instruments for the 24-forecasts for February 2007 - 1/2degree system

Source: Gelaro, Rienecker et al., 2008, NASA GMAO
ATMS Precipitation Retrieval: Improvements Relative to AMSU

Source: Surussavadee and Staelin
ATMS Storm Mapping: Improvements Relative to AMSU

Source: Surussavadee and Staelin
Summary

• ATMS on-orbit performance has been excellent
• Cal/val activities in progress to optimize calibration parameters
• AMSU capabilities will be continued and expanded
• Precipitation products look to be markedly improved from AMSU
Backup Slides
Utility of Aircraft Underflights

What do aircraft measurements provide that we cannot get anywhere else?
   - Why not just compare to radiosondes or NWP?

- Direct radiance comparisons
  - Removes modeling errors

- Mobile platform
  - High spatial & temporal coincidence achievable

- Spectral response matched to satellite
  - With additional radiometers for calibration

- Higher spatial resolution than satellite

- Additional instrumentation deployed
  - Coincident video data
  - Dropsondes

Example video image:
- Solar glint
- Ocean
- Clouds
New Products: Precipitation Rate

Fig. 12. Surface-precipitation rates (mm h$^{-1}$; 15-min integration) for (a) summer frontal system over France at 1003 UTC 2 Jan 2003, (b) ITCZ at 0553 UTC 15 Apr 2003, (c) snow (top half) plus rain (bottom half) over land at 0423 UTC 10 Nov 2002; the threshold is 0.25 mm h$^{-1}$, and (d) nonglaciated system over ocean at 0503 UTC 16 Nov 2002. From top to bottom are displayed the MM5-simulated values, the instantaneous AMSU retrieval, and the two-sample 15-min GEM retrieval.

Image credit: C. Surussavadee
Backup Slides
NPOESS Preparatory Project

- Launch site: Vandenberg AFB
- Launch vehicle: Boeing Delta II
- Spacecraft: Ball Aerospace Commercial Platform 2000
- Instruments: VIIRS, CrIS, ATMS, OMPS, & CERES
- Orbits: 824 km (NPP); sun-synchronous with a 1:30 p.m. local-time ascending node crossing

NPP (NPOESS Preparatory Project)
Oct. 28, 2011 Launch

National Polar-orbiting Operational Environmental Satellite System → Joint Polar Satellite System
### ATMS Data Products

<table>
<thead>
<tr>
<th>Data Product</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>RDR (Raw Data Record)</td>
<td>FOV(^1) antenna temperature (counts)</td>
</tr>
<tr>
<td>TDR (Temperature Data Record)</td>
<td>FOV(^1) antenna temperature (K)</td>
</tr>
<tr>
<td>SDR (Sensor Data Record)</td>
<td>FOR(^1) brightness temperature (K)</td>
</tr>
<tr>
<td>EDR (Environmental Data Record)</td>
<td>P/T/WV profile</td>
</tr>
<tr>
<td>“CDR” (Climate Data Record)</td>
<td>“Climate-optimized” product</td>
</tr>
<tr>
<td>IP (Intermediate Product)</td>
<td>Used to generate EDR/CDR</td>
</tr>
</tbody>
</table>

\(^1\)FOV = ATMS “Field of View”; FOR = CrIMSS “Field of Regard”

RDR, TDR, SDR, and EDR products will be available via CLASS
ATMS On-Orbit FOV Characterization

- Spacecraft maneuvers (constant pitch up or roll, for example) could be used to sweep antenna beam across vicarious calibration sources
  - Moon (probably too weak/broad for pattern assessment)
  - Earth’s limb (requires atmospheric characterization)
    Focus of today’s presentation
  - Land/sea boundary (good for verification of geolocation)

- With knowledge of the atmospheric state, the antenna pattern can be recovered with deconvolution techniques

- Objectives of this study - quantitatively assess:
  - The benefits of various maneuvers
    How accurately can the pattern be recovered?
  - The limitations of this approach
    How much roll/pitch is needed for an adequate measurement?
    The error sources and their impact
T_b’s Across Earth/Space Transition

Standard atmosphere from 833 km over calm ocean

LIMB
(STANDARD ATMOSPHERE)

SURFACE

62.17°

Satellite scan angle [degrees]

Brightness Temp. [K(in)]

50.3
51.76
52.8
53.711
54.4
54.94
55.5
57.29

BEYOND STANDARD ATMOSPHERE
NPOESS Airborne Sounder Testbed

OBJECTIVES

• Satellite calibration/validation
• Simulate spaceborne instruments (i.e. CrIS, ATMS, IASI)
  — Preview high resolution products
  — Evaluate key EDR algorithms

INSTRUMENTS: NAST-I & NAST-M

NAST- I: IR Interferometer Sounder
NAST- M: Microwave Sounder

5 Bands: 23/31 (to be added), 54, 118, 183, 425 GHz

Cruising altitude: ~17-20 km
Cross-track scanning: - 65° to 65°
MetOp Satellite Validation

JAIVEx
April 20th, 2007 collection

Gulf of Mexico

<20min

AMSU-A (MetOp) [Kelvin]

T_b Comparison AMSU-A

GHz  Bias
50.3  -0.25K
52.8  1.4K
53.75 -0.2K
54.4  -0.2K
54.94 -0.9K

NAST-M [Kelvin]

Applied:
17.5km NAST-M altitude correction
1.6K RTD corr.
Lab Spillover corr.
Center 3 NAST-M spots only
Center 6 Sat footprints only

AMS-27
WJB 2/15/2012

1951–2011
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